IN-25
76861
10P

NASA CASE NO. LAR-13,597-1CU

PRINT FIG. 1

NOTICE

The invention disclosed in this document resulted from research in aeronautical and space activities performed under programs of the National Aeronautics and Space Administration. The invention is owned by NASA and is, therefore, available for licensing in accordance with the NASA Patent Licensing Regulation (14 Code of Federal Regulations 1245.2).

To encourage commercial utilization of NASA-owned inventions, it is NASA policy to grant licenses to commercial concerns. Although NASA encourages nonexclusive licensing to promote competition and achieve the widest possible utilization, NASA will consider the granting of a limited exclusive license, pursuant to the NASA Patent Licensing Regulations, when such a license will provide the necessary incentive to the licensee to achieve early practical application of the invention.

Address inquiries and all applications for license for this invention to NASA Patent Counsel, Langley Research Center, Mail Code 279, Langley Station, Hampton, VA 23665. Approved NASA forms for application for nonexclusive or exclusive license are available from the above address.

LaRC

(NASA-Case-LAR-13597-1-CU) APPARATUS AND PROCEDURE TO DETECT A LIQUID-SOLID INTERFACE DURING CRYSTAL GROWTH IN A BRIDGMAN FURNACE Patent Application (NASA) 10 p Avail: NTIS HC A02/MF A01 CSCL 07D G3/25

N87-23713

Unclas
0076861

AWARDS ABSTRACT LAR-13597-1-CU

APPARATUS AND PROCEDURE TO DETECT A LIQUID-SOLID INTERFACE DURING CRYSTAL GROWTH IN A BRIDGMAN FURNACE

This invention relates to a method and apparatus for detecting a liquid-solid interface of a substance. In particular, the invention detects the liquid-solid interface of a semiconductor crystal grown in a Bridgman furnace.

As illustrated in the drawings, a substance, such as germanium, in a Bridgman furnace 10 is irradiated by solid-penetrating energy from a radiation source 12. The solid-penetrating energy is detected by a radiation detector 14. Differences in the intensity of the detected energy indicate the shape of the liquid-solid interface. In the case of germanium, X-rays can be used as the solid-penetrating energy, while in the case of a substance such as lead tin telluride, gamma rays are preferable.

The invention enables detection of the shape of the liquid-solid interface of a semiconductor substance during growth of a crystal formed from the substance. Variations in several characteristics of semiconductor crystals are believed to be related to the shape of the liquid-solid interface, but previously there was no means to detect the shape of the liquid-solid interface during growth of the crystal.

Inventor(s):	Patrick G. Barber	Roger K. Crouch
Home Address:	Route 2, Box 29B Keysville, VA 23947 [redacted]	2611 Fort Drive Alexandria, VA 22303 [redacted]
Employer:	Longwood College	NASA Headquarters
Inventor(s):	Archibald L. Fripp, Jr.	Robert F. Berry, Jr.
Home Address:	125 Little John Road Williamsburg, VA 23185 [redacted]	Route 3, Box 259 Hayes, VA 23072 [redacted]
Employer:	NASA - LaRC	NASA - LaRC
Inventor(s):	William J. Debnam, Jr. 321 Beechmount Drive Hampton, VA 23669 [redacted]	Richard T. Simchick 58 Whetstone Drive Hampton, VA 23666 [redacted]
Employer:	NASA - LaRC	PRC - Kentron, Inc.

Initial Evaluator: Fred Staggs

Serial No.: 008199
Filed: January 29, 1987

FIG. 1

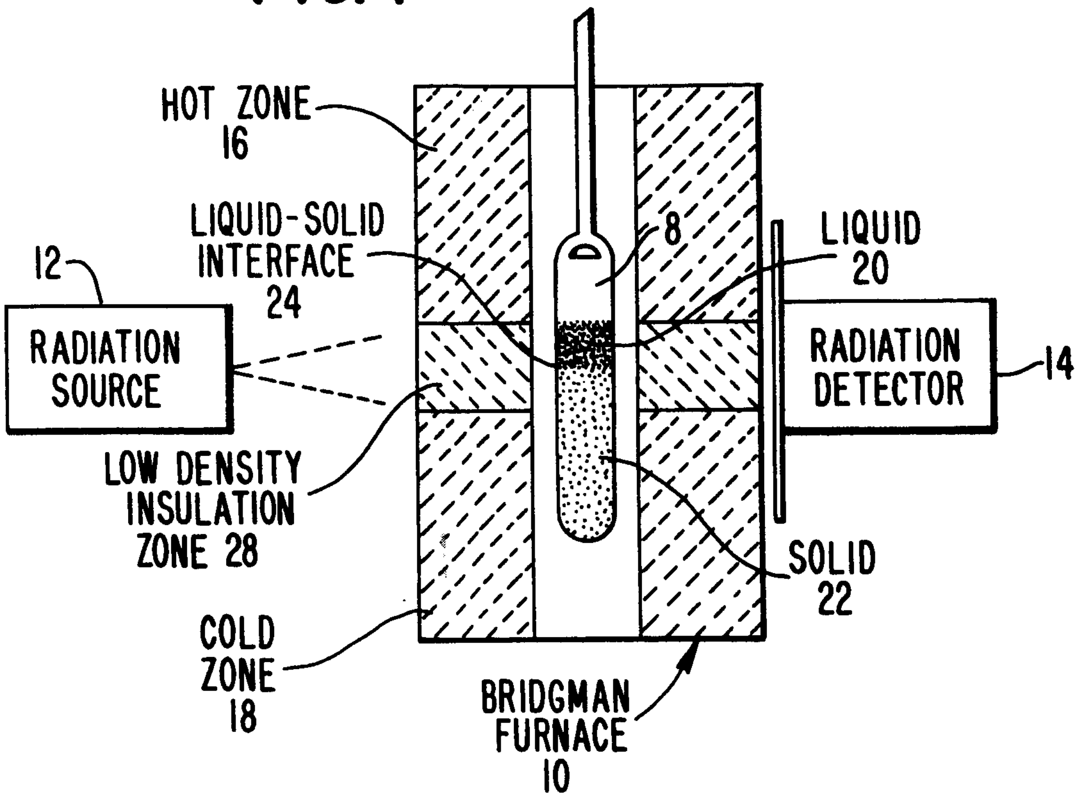


FIG. 2A

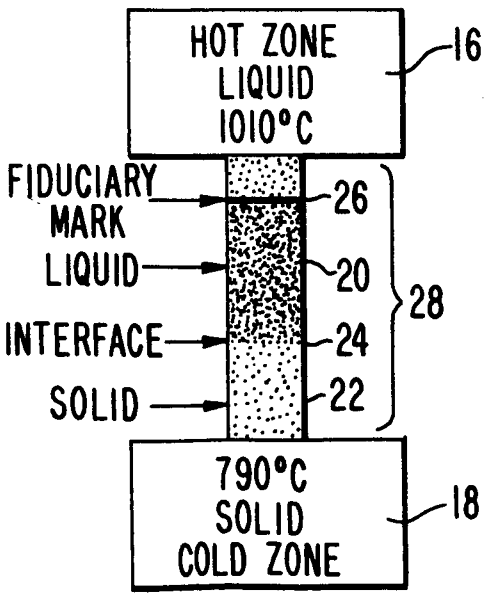
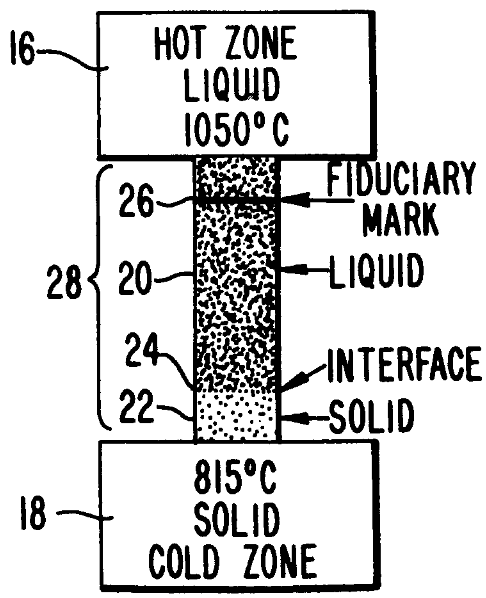


FIG. 2B



Patrick G. Barber et al

LAR 13597-1-CU APPARATUS AND PROCEDURE TO DETECT A LIQUID-SOLID INTERFACE DURING CRYSTAL GROWTH IN A BRIDGMAN FURNACE

FIG. 3A

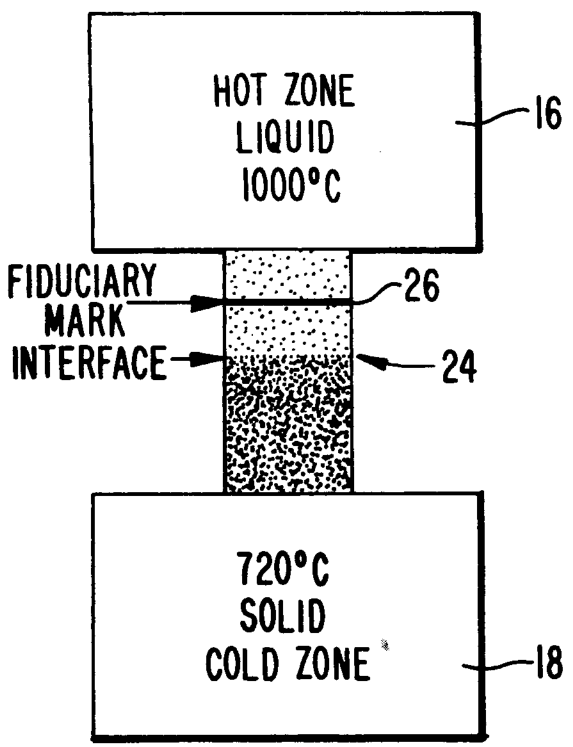
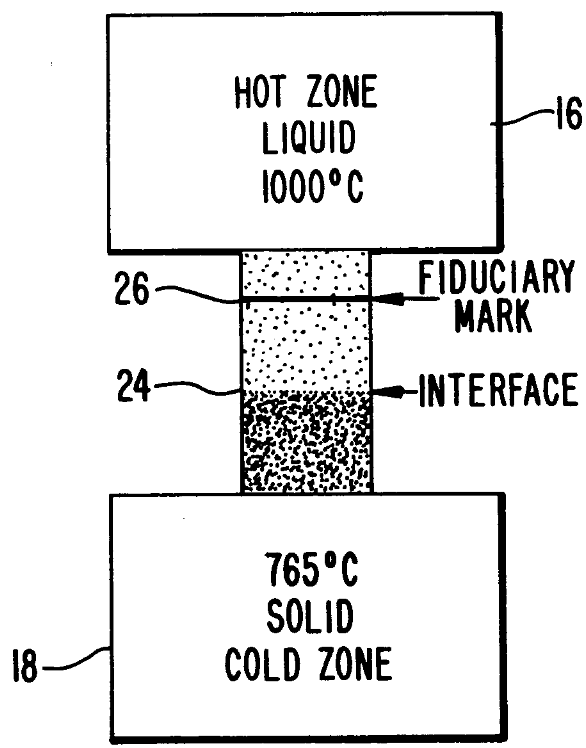

HOT ZONE
LIQUID
1000°C
16
FIDUCIARY
MARK
26
INTERFACE
24
720°C
SOLID
COLD ZONE
18

FIG. 3B


HOT ZONE
LIQUID
1000°C
16
26
FIDUCIARY
MARK
24
INTERFACE
765°C
SOLID
COLD ZONE
18

Title of the Invention

APPARATUS AND PROCEDURE TO DETECT A LIQUID-SOLID INTERFACE DURING CRYSTAL GROWTH IN A BRIDGMAN FURNACE

Origin of the Invention

The invention described herein was made in the performance of work under a NASA Contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 435; 42 USC 2457).

Background of the Invention

Field of the Invention

The present invention is related to a method and apparatus for detecting a liquid-solid interface and, more particularly, to a method and apparatus which can be used to detect the liquid-solid interface of crystals formed from germanium or lead tin telluride in a Bridgman furnace.

Description of the Related Art

It has long been known that the shape of the liquid-solid interface during solidification of semiconductor crystals significantly alters the final properties of the crystal. Properties which may be affected include impurity distribution, defect generation, and effects caused by the flow patterns in a system with radial temperature and solutal gradients. However, heretofore, all investigation of the correlation between interface shape and these

effects has required that the analysis be performed after the crystal growth is completed, because there has been no known way to detect the shape of the liquid-solid interface during crystal growth.

There are known techniques for detecting gas-liquid and gas-solid interfaces of a substance, e.g., U.S. Patents 3,668,392 to Bajek et al. and 4,358,682 to Telfer et al. and also for detecting interfaces between dissimilar substances, such as between molten metal and slag as taught by U.S. Patent 4,433,242 to Harris et al. However, in addition to not detecting a liquid-solid interface of a single substance, all three of these patents are directed to detecting the location of the interface rather than its shape.

Summary of the Invention

An object of the present invention is to detect a liquid-solid interface of a single substance.

Another object of the present invention is to provide a two-dimensional view of a liquid-solid interface of a substance.

A further object is to detect growth of a crystal in a Bridgman furnace.

A yet further object of the invention is to control a Bridgman furance to provide a desired liquid-solid interface shape and position of a substance by first viewing the radiation image thereof.

The above objects are attained by detecting a liquid-solid interface of a substance using a method which includes the steps of irradiating the substance with a solid-penetrating energy output by a radiation source and detecting differences in intensity of the solid-penetrating energy in a detection area having at least two dimensions. The substance is disposed between the radiation source and

the detection area. A first level of intensity results from passage through a liquid portion of the substance and a second level of intensity results from passage through a solid portion of the substance.

Preferably, gamma rays or X-rays are used as the solid-penetrating energy which irradiates the substance. The solid portion of the substance may be a crystal which is being produced by controlling temperature in the area of the liquid-solid interface.

The steps described above may be used to detect a liquid-solid interface formed during growth of a crystal using energy direction means for directing solid-penetrating energy onto a first side of the crystal at a first area including a liquid-solid interface and detection means for detecting intensity of the solid-penetrating energy in a second area facing a second side, opposite the first side of the crystal.

These objects, together with other objects and advantages which will be subsequently apparent, reside in the details of construction and operation as more fully hereinafter described and claimed, reference being had to the accompanying drawings forming a part hereof, wherein like reference numerals refer to like parts throughout.

Brief Description of the Drawings

FIG. 1 is a schematic diagram of an apparatus according to an embodiment of the present invention;

FIGS. 2A and 2B are illustrative of the image formed on X-ray film by X-rays which have passed through a Bridgman furnace in which a germanium crystal is being formed; and

FIGS. 3A and 3B are illustrative of the image formed by detecting gamma rays which have passed through a Bridgman furnace in which a lead tin telluride crystal is being grown.

Description of the Preferred Embodiments

As illustrated in FIG. 1, a substance 8 is supplied to a Bridgman furnace 10, which was constructed by the inventors, to grow a crystal. A radiation source 12 irradiates the substance 8 from a first (left) side of the Bridgman furnace 10. A radiation detector 14 on a second (right) side of the Bridgman furnace detects differences in intensity of the solid-penetrating energy output by the radiation source 12. For example, when germanium is used as the substance 8, X-rays may be used as the solid-penetrating energy, since germanium has a relatively low atomic number and is thus penetrated by X-rays. In this case, the radiation source 12 may be a Model SPX 160 X-ray tube, manufactured by Automation Industries of Danbury, Connecticut, and the radiation detector 14 could include X-ray sensitive film, such as Kodak Type M Radiographic film, manufactured by Eastman Kodak Company of Rochester, New York. The X-ray sensitive film produces a record of the radiation intensity in a two-dimensional area on the second side of the Bridgman furnace.

A Bridgman furnace is illustrated in FIG. 2A which has a hot zone 16 producing liquid germanium at a temperature of 1040°C and has a cold zone 18 set at 790°C. Theoretically, there should be an X-ray density difference between the liquid germanium 20 and solid germanium 22 of approximately four percent. As a result, an interface 24 is formed as illustrated. In the illustrated embodiment, a fiduciary mark 26 is formed to provide a reference point by, e.g., a ceramic coating on shuttle tile material used to provide an insulation zone 28 in the portion of the Bridgman furnace in which the crystal is grown. The effect of increasing the temperature of the hot 16 and cold 18 zones is illustrated in FIG. 2B where the interface 24 between the liquid 20 and solid 22 is noticeably lower.

In the case of substances that are high in atomic number, such as lead tin telluride, gamma rays can be used as a solid-penetrating energy to produce images such as those illustrated in FIGs. 3A and 3B for different cold 18 zone temperature settings. In this case, the radiation source 12 may be an Irridium 192, 0.1 inch x 0.1 inch right cylinder, manufactured by Gamma Industries of Baton Rouge, Louisiana, and the radiation detector 14 could be Kodak Type M Radiographic film. When lead tin telluride is grown vertically downward, i.e., hot-on-the-bottom, it develops a central void along its length. The development of such a void can be followed by taking a series of "pictures" using gamma radiation.

The many features and advantages of the present invention are apparent from the detailed specification, and thus, it is intended by the appended claims to cover all such features and advantages of the device which fall within the true spirit and scope of the invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation illustrated and described. Accordingly, all suitable modifications and equivalents may be resorted to falling within the scope and spirit of the invention. For example, it is expected that the images provided can be improved using computer aided image enhancement and that an electronic array can be used as the radiation detector 14 in place of X-ray sensitive film.

What is claimed is:

APPARATUS AND PROCEDURE TO DETECT A LIQUID-SOLID INTERFACE DURING CRYSTAL GROWTH IN A BRIDGMAN FURNACE

Abstract of the Disclosure

A method of detecting a liquid-solid interface of a substance includes irradiating the substance with a solid penetrating energy and detecting differences in intensity of the solid-penetrating energy which passes through the substance. A first level of intensity results from passage through a liquid portion of the substance and a second level of intensity results from passage through a solid portion of the substance.